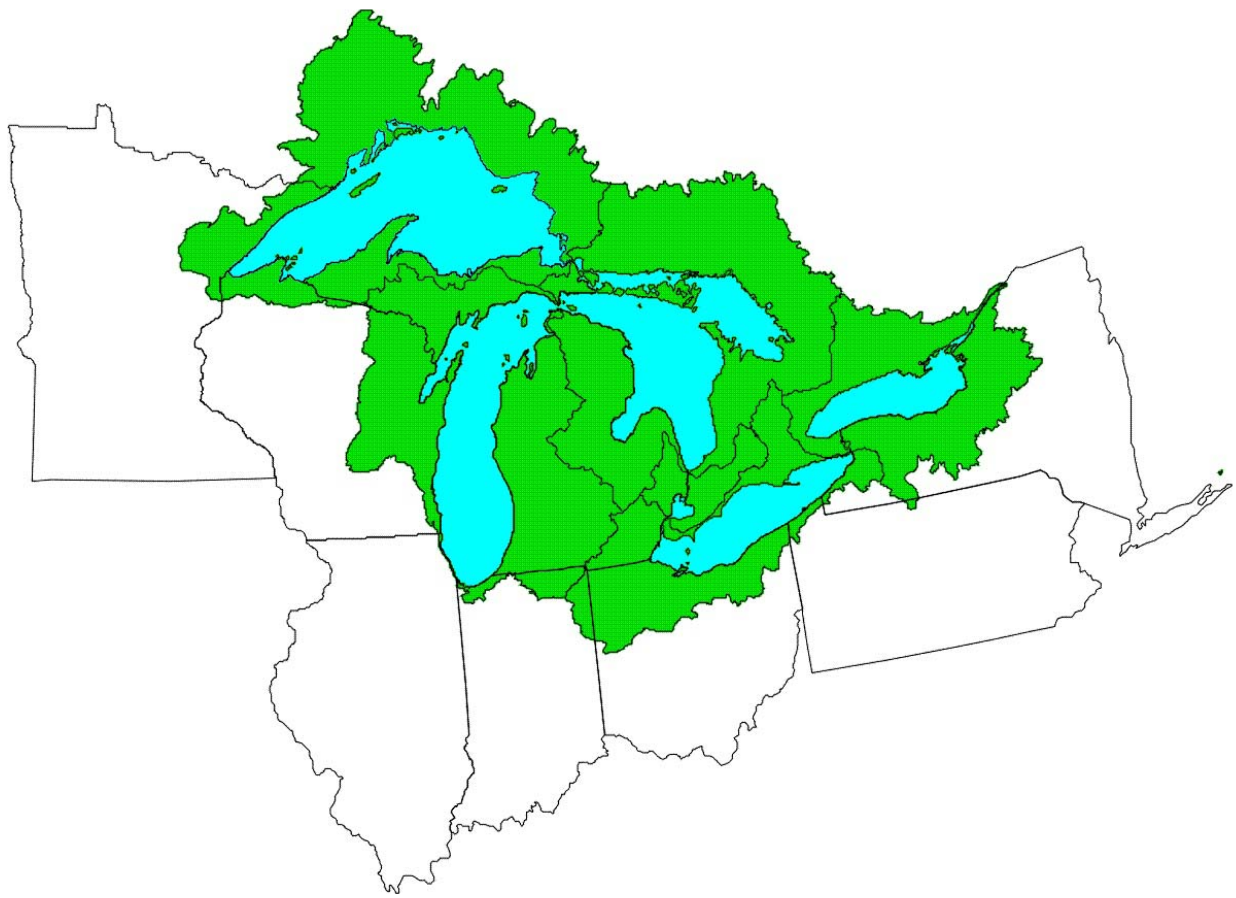
# Improvements to the Great Lakes – St. Lawrence River Biohydrological Information Base

**In response to Public Law 106-53, Water Resources Development Act of 1999, Section 455(b), John Glenn Great Lakes Basin Program, Great Lakes Biohydrological Information**

**Appendix H: Water Quantity Impacts on Great Lakes – St. Lawrence River Organisms**



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US Army Corps of Engineers®

# Measurement Converter Table

## U.S. to Metric

**Length**
feet x 0.305 = meters
miles x 1.6 = kilometers

**Volume**
cubic feet x 0.03 = cubic meters
gallons x 3.8 = liters

**Area**
square miles x 2.6 = square kilometers

**Mass**
pounds x 0.45 = kilograms

## Metric to U.S.

**Length**
meter x 3.28 = feet
kilometers x 0.6 = miles

**Volume**
cubic meters x 35.3 = cubic feet
liters x 0.26 = gallons

**Area**
square kilometers x 0.4 = square miles

**Mass**
kilograms x 2.2 = pounds

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# APPENDIX H:

## Water Quantity Impacts on Great Lakes - St. Lawrence River Organisms

### Introduction

The Great Lakes - St. Lawrence River basin was formed by the forces of water and ice. While water is the root of existence for all organisms, a functioning ecosystem thrives on a healthy environment and the interactions among a complex arrangement of species. Although many species and their functions are not fully understood, it is apparent that each every species plays an important role in the ecosystem.

In this appendix, organisms have been separated by taxonomic classifications. Four kingdoms belong to this domain: Protista, Fungi, Plantae and Anamalia. The Kingdom Protista is composed of protist species that are unicellular, colonial, or multicellular. They are carbon sinks and form the base of the aquatic food chain. These protists include algae (phytoplankton), slime molds and protozoans (zooplankton). Protists are generally found in aquatic environments since their locomotive capabilities are minimal, although slime molds are found in moist terrestrial systems. The Kingdom Fungi are mostly multicellular decomposers, represented by mushrooms, molds, yeasts and lichens. Fungi are nutrient recyclers that make carbon and nutrients available for uptake by plants. The Kingdom Plantae is composed of multicellular, autotrophic organisms that photosynthesize to fix inorganic carbon into organic molecules. This kingdom is represented by mosses, ferns, conifers and flowering plants. These plants are the primary producers of the system, providing food for the Kingdom Animalia. The Kingdom Animalia consists of invertebrates, fish, amphibians, reptiles, birds and mammals.

Appendix G, *Water Quantity Impacts on Great Lakes Ecosystems*, describes the habitats of the Great Lakes - St. Lawrence River region and recommends ways to improve the understanding of relationships between hydrology and ecosystem health. As an essential component to habitats, the various classes of organisms found in Great Lakes habitats are described in this appendix. Furthermore, this appendix assesses the current state of data and information for each particular group of organisms. As a part of the Great Lakes Biohydrologic Information Systems Study, data and information related to organisms are inventoried and presented in the last section of this appendix. The information generated by this inventory is summarized in the body of this appendix by organism group. Additionally, gaps in data and information for each organism group are assessed in the body of this appendix. However, different from the other appendices of this study, recommendations to fill these information gaps are not developed.

In conducting the search for data on water withdrawals and how they affect organisms, it became clear that little information is currently available on this topic. While many organisms have been intensively studied, others are greatly lacking in basic ecological data. To determine the effects of water withdrawals on every organism in the system is a bit redundant when we can determine the effects of withdrawals on the habitat, for it is the habitat that determines the species assemblage. The scope of this study does not support the cost or time to assess impacts to individual organisms.

Nevertheless, it would be of great importance in the aquatic environment to determine how water withdrawal affects *Diporeia spp.*, a tiny shrimp-like crustacean and plankton since these organisms form the base of the aquatic food web. These organisms are currently State of Lakes Ecosystem Conference (SOLEC)[1] indicator organisms and future funding should be funneled to research these keystone organisms.

In summary, this appendix:

1) describes the grouping of organisms found in the Great Lakes - St. Lawrence River basin;
2) describes the data and information currently available for each organism group; and
3) identifies gaps in these data and information.

## Protists

### Algae

Algae are simple single-celled, colonial, or multi-celled, aquatic plants. Aquatic algae are mostly microscopic plants that contain chlorophyll; grow by photosynthesis; and lack roots, stems and leaves (Reid and Holland, 1997). They absorb nutrients from the water or sediments and are usually the major source of organic matter at the base of the food web in lakes. Millions of species of bacteria and fungi play a critical role in breaking down organic material and reprocessing the nutrients to make them available for algae to continue growing (Reid and Holland, 1997). In addition to sitting at the foundation of the food web that supplies energy to all other organisms on the planet, algae have the potential to act as a "carbon sink," sucking up and storing excess carbon dioxide and moderating climate change.

Algae, as well as plants, are responsible for transforming carbon dioxide from the atmosphere into the usable forms of carbon that serve as the building blocks for life by photosynthesis. Freely suspended forms are called phytoplankton; forms attached to rocks, stems, twigs and bottom sediments are called periphyton. Algae are a major food source in the aquatic ecosystem. Zooplankton, mussels, larval fish, and other small fish thrive on algae, phytoplankton and periphyton.

Algae are often overlooked, but they are very important to riverine health. Rivers and streams typically contain hundreds of algal species and many indicate environmental health by their presence under specific water-quality conditions. Excess nutrients such as nitrogen and phosphorus originating from fertilizers or animal wastes usually will increase the amount of nuisance algal growth. The resultant dense mats of algae can choke off waterways to boaters and, through decay and respiration can reduce oxygen to levels lethal to fish and other aquatic organisms (Reid and Holland, 1997).

Altered water flow and levels can have several affects on the aquatic algal communities. Water flow is slowed by natural or manmade impediments, making calmer waters. Calmer water lets in more sunlight and slower moving water usually has a higher temperature. This changes the algal communities and algal species that are accustomed to low oxygen levels thrive, often forming algal blooms or mats and decreasing the available amount of oxygen to

[1] SOLEC is hosted by the U.S. Environmental Protection Agency and Environment Canada on behalf of the two countries. These conferences are held every two years in response to a reporting requirement of the binational Great Lakes Water Quality Agreement (GLWQA). The purpose of the Agreement is "to restore and maintain the physical, chemical and biological integrity of the Great Lakes Basin." The conferences are intended to report on the state of the Great Lakes ecosystem and the major factors impacting it and to provide a forum for exchange of this information amongst Great Lakes decision-makers.

other organisms (Reid and Holland, 1997). Algal populations are also decreased with an increase in water movement (Munawar and Munawar, 2000).

The U.S. Geological Survey (USGS) has distributional data of aquatic species and habitats including algae for all the Great Lakes. The Fish and Wildlife Service (FWS) has algae studies for east-central Lake Superior. NOAA has seasonal and spatial distributional data for algal blooms in Saginaw Bay, Lake Superior and is developing a invasive species database that include algae for all of the Great Lakes. U.S. Environmental Protection Agency (USEPA) has several phytoplankton studies throughout the Great Lakes and is working on phytoplankton spatial data for Saginaw Bay. Environment Canada has biological information, including 20-year overview of algal species, for the St. Lawrence River.Lakes - St. and Environment Canada monitor phytoplankton populations under SOLEC (State of the Lakes Ecosystem Conference) as a Great Lakes indicator.

The understanding of phytoplankton and their role in the Great Lakes Ecosystem is weak. Although numerous research efforts on phytoplankton exist in the Great Lakes, little effort has been made to standardize methodology to ensure data quality and comparability (Munawar and Munawar, 2000). Most of the information referenced above is in report format. It would be useful to have algal species distribution, population size and vertical migration in a standardized spatial database for the entire Great Lakes system. Seasonal variation in species could be determined and the affects of water levels on algal diversity and abundance could be determined with the use of GIS.

**Slime Molds**
The slime molds are not closely related to any other living organisms. They are unicellular, multicellular and colonial at different stages of their life cycles. They thrive in moist environments with decaying organic matter, bacteria and yeasts. There are two main groups of slime molds: cellular and plasmodial. When there are high numbers of bacteria available as food, cellular slime molds are solitary amoeboid cells that engulf bacteria. When bacteria become scarce, the amoeboid cells aggregate into a sluglike colony, which soon grow into a multicellular reproductive structure. In these two stages, the individual cells secret a slimy covering coated with cellulose. Many slime molds thrive in forests within and on moist bark, rotting logs, leaf litter, dung and soil. They are significant decomposers, contributing to the maintenance of nutrient cycling. They are also utilized as food for many protozoa, nematodes, small arthropods and other small creatures.

Temperature and moisture have been shown to be the primary factors influencing seasonal distribution (Moore, 2002). While slime molds are dependent on a moist environment, precise knowledge of how water regimes influence these organisms is absent. It is likely that a lowered water table would limit the abundance and distribution of these organisms, which in turn would limit the amount of nutrient recycling or decomposition.

Knowledge of slime mold ecology is severely lacking. Currently, less than 20 people in the United States actively study these organisms (Moore, 2002). As a result, the knowledge of their ecology is limited to the particular location where these individuals carry out their research.

**Protozoans**
The name protozoa means “first animal” and they are often referred to as zooplankton. Protozoans play an indispensable role in biogeochemical cycles and therefore also in the biosphere (Klijn, 1994)). They are abundant in deep lake waters as well as near the surface.

Ponds, streams, rivers, swamps, most soil and even the very acidic water caused by industrial pollution contain some species of protozoa. Protozoans typically obtain their nutrition by engulfing food particles and small nutrient molecules from the environment. Protozoans consume a variety of prey. Many smaller protozoans feed on bacteria, some use algae as food and others that are large enough may consume other protozoans. As the principal hunters and grazers of the microbial world, protozoans/zooplankton play a key role in maintaining the balance of bacterial, algal and other microbial life. They are an important food source for larger creatures such as fish and invertebrates and form the basis of many food chains.

Any disturbance such as nutrient enrichment, fish introductions, thermal discharges or toxic effluents that alter the composition of the zooplankton community could ultimately affect the rest of the system (Schneider *et al.*, 1989). Research on protozoans has mainly focused on these types disturbances, and little is known about the impacts of water quantity on protozoans. However, it is conceivable that a change in hydrologic regime would affect the diversity and abundance of the protozoan population which would in turn upset the entire aquatic ecosystem.

The USGS has distributional data of aquatic species and habitats, including protozoans, for all the Great Lakes. Additionally, the USGS also has zooplankton data for the nearshore of Lake Erie and for the Sleeping Bears Dunes National Lakeshore. NOAA has information on the zooplankton of Lake Michigan and a report on the effects of the zebra muscle on protozoans from Saginaw Bay. The USEPA has a biological open water surveillance program for all of the Great Lakes and information on the zooplankton from Lakes Michigan and Ontario. The USEPA and Environment Canada have created the SOLEC indicator database, monitoring zooplankton populations in the Great Lakes.

A long term monitoring study of zooplankton distribution, diversity, vertical migration and abundance should be developed to determine if water levels affect the livelihood of these organisms. Distribution is not well documented (Klijn, 1994).

## Fungi

**Mushrooms**

The mushroom is a significant element of the forest ecology. Mushrooms decompose brush and dead or diseased trees releasing nutrients back into the ecosystem. This assists in recycling critically limited nutrients such as nitrogen back into the soil. The visible part of a mushroom is the fruiting body that produces and releases spores for reproduction when temperature and moisture conditions are optimal (Kendrick, 2002). The living part of the mushroom is underground in the form of hyphae, tiny web-like filaments (Alexopoulus *et al.*, 1996). Typical forest mushrooms include morels (*Morchella* spp.), giant puffballs (*Calvatia gigantea*), death caps (*Amanita phalloides*), and Old man of the woods (*Strobilomyces confusus*). Mushrooms not only make nutrients available for a number of plants, they are also a food source for many woodland animals, including slugs, insects, squirrels, rabbits, and turtles. Mushrooms depend on moist conditions to develop their fruiting bodies for reproduction (Starr, 2000). It is unlikely that a lowered water table will adversely affect most mushrooms.

No government agencies are currently collecting data on mushrooms. NatureServe has distributional data on species and habitat throughout the Great Lakes - St. Lawrence River basin. The Chicago Field Museum has an online database of fungal information for the

Great Lakes - St. Lawrence River basin. Research is needed to determine how cumulative water withdrawals will affect mushrooms.

**Molds and Mycorrhizae**

Like mushrooms, molds and mycorrhizae are decomposing fungi, releasing nutrients back into the system. However, a few molds are also parasitic, living off a host plant or animal and sacrificing the host's health (Stamets, 1999-2004). Water molds are found in wet environments, especially in freshwater sources and near the upper layers of moist soil. Some water mold species, such as *Saprolegnia*, can cause disease in fish. These parasitic molds are typically thought of as biologically evil causing much damage to a number of plant and animal species; however, a new species called *Taxomyces andreanae* produces minute quantities of the anti-carcinogen Taxol which is a proven treatment for breast cancer (Stone, 1993). Many plants have a similar relationship with mycorrhizae, fungi found in the soil that promote plant growth and nutrient absorption. Rather than merely decomposing organic matter, they have a vital symbiotic relationship with trees and other green plants.

At least 80 percent of all land plants, including all trees, have mycorrhizal fungi (Starr, 2000). The plant "feeds" the fungus some of the carbohydrates it makes through photosynthesis. In return, the fungus increases the plants' root absorption of water and certain essential minerals, such as phosphorus and magnesium. Without mycorrhizal fungi, most plants, including the grasses, would not survive and thrive. Knowledge of how water quantity affects molds and mycorrhizae is poorly understood. It is unlikely that a lowered water table will have much affect on the livelihood of these organisms. No agencies are collecting data on molds or mycorrhizae. At a minimum, distributional data on these organisms are needed.

**Yeasts**

Yeasts are crucial components of the food chain. For each plant and animal, there are specific microorganisms associated with that particular species. Industrial and agricultural yeasts have been well described, however, not much is known about their ecological roles. Yeasts provide a source of sterols for invertebrates and stimulate growth and nitrogen-fixing in bacteria. They also provide a mechanism for uptake, accumulation and transformation of phosphorus for use in the food web. Yeasts, in the natural environment, are poorly understood. It is unlikely that a lowered water table will have much affect on the livelihood of these organisms. No agencies are collecting data on yeasts. At a minimum, distributional data on these organisms are needed.

**Lichen**

Lichens are the result of a fungus intertwined with an algae or cyanobacteria. Algae put together and excrete a certain carbohydrate that is taken up and used as food by the fungus. Fungi provide water, minerals and shelter for algae. Together, lichens exploit habitats where the fungi or the algae could not survive independently, typically on rocks, bark or poor soil. Lichens play important roles in the complex food webs of forests, providing food sources for many organisms. For example, certain lichen species provide food for Flying Squirrels (*Glaucomys sabrinus*), the prey for many owls, hawks, martens and weasels. Other lichens are important winter food sources for browsing deer and elk. Many other lichens play an important ecological role in the fixation of nitrogen for the forest.
Lichens are dependent on water. Their life cycle is dependent on the presence of water. During times of drought, lichens cease to reproduce and grow. When water is more plentiful, they resume growth and reproduction. Specific literature on how water withdrawal affects these organisms does not exist, but the effects are likely minimal.

Only a few agencies collect information on lichens. The U.S. Department of Agriculture (USDA) Forest Service has distributional and biological information on lichens in the Great Lakes - St. Lawrence River basin. NatureServe also has distributional information on lichens in the Great Lakes - St. Lawrence River basin. Environment Canada has biological information for the St. Lawrence River. The Ontario Ministry of Natural Resources (OMNR) has distributional data for lichens in Ontario Further research is needed to determine the impacts of water withdrawal on these organisms.

## Plants

### Mosses

Mosses, liverworts and hornworts are bryophytes, non-vascular plants adapted to moist habitats. Bryophytes form extensive mixed communities and contribute significantly to community structure and ecosystem functioning. They are critical to the survival of a tremendous diversity of organisms, including insects, millipedes and earthworms. Many arthropods are dependent on mosses and liverworts as habitat or as a food source. The moss' nutrient-rich, spore-producing capsules are particularly palatable to some insects and mollusks such as slugs. Mosses are also a food source for birds and mammals in cold environments and are eaten by geese, ducks, sheep and rodents. In addition to providing an important food source, mosses also provide seed beds for the larger plants of the community. They capture and recycle nutrients that are washed with rainwater from the canopy and they bind the soil to keep it from eroding. Mosses are "pioneer" species - the first organism to inhabit areas highly degraded by human action (Shaw and Goffinet, 2000).

Mosses are especially sensitive to air pollution (Adams and Preston, 1992). They have a low tolerance of rivers that are dammed, polluted and contain fine sediments (Lopez *et al.*, 1997). They are most demanding of rapid currents, clean water and rocky/open gravel conditions. They are extremely dependent upon water for their survival and reproduction and are therefore typically found in moist areas like creeks and forests (Shaw and Goffinet, 2000). Some bryophytes, however, are able to survive in areas with little or no rainfall.

The USDA Forest Service has distributional and biological information on mosses in the Great Lakes - St. Lawrence River basin. The Natural Resources Conservation Service (NRCS) has distributional and biological information for plants, mosses, liverworts, hornwort and lichens in the Great Lakes - St. Lawrence River basin. NatureServe also has distributional information on mosses in the Great Lakes - St. Lawrence River basin. The National Biological Information Infrastructure has online information on plants, mosses, liverworts, ferns and animals of the Great Lakes - St. Lawrence River basin. Environment Canada has biological information for the St. Lawrence River and in conjunction with the USEPA has created the SOLEC indicator database for the Great Lakes - St. Lawrence River basin, including the presence of bryophytes. The OMNR has distributional data for mosses in Ontario. While data exists for mosses, further research is needed to determine the impacts of water withdrawal on these organisms.

### Ferns

Ferns and other seedless vascular plants are found all over the world, from sea-level to high mountains. They are descended from some of the oldest plants of the earth's history, being found as fossils dating back nearly 400 million years (Starr, 2000). A very diverse group of plants, ferns are found primarily in moist tropical areas, thinning out to the north. Ferns play an important role in ecological succession, often colonizing rock crevices, old fields, or open marshes preparing the soils and providing a seedbed for woody vegetation.

Ferns are dependent upon moist conditions, utilizing water droplets to aid in fertilization. Ferns are the "amphibians" of the plant kingdom, still connected to the aquatic habitats of their ancestors (Starr, 2000). Like other bryophytes, ferns are sensitive to water pollution, yet it is not know how lowered water tables affect these plants.

The USDA Forest Service has distributional and biological information on ferns in the Great Lakes - St. Lawrence River basin. The NRCS has distributional and biological information for ferns in the Great Lakes - St. Lawrence River basin. NatureServe also has distributional information on ferns in the Great Lakes - St. Lawrence River basin. The National Biological Information Infrastructure has online information on ferns of the Great Lakes - St. Lawrence River basin. Environment Canada has biological information for the St. Lawrence River and in conjunction with the USEPA has created the SOLEC indicator database full of biodiversity information for the Great Lakes - St. Lawrence River basin, including the presence of bryophytes. The OMNR has distributional data for plants in Ontario. The Canadian Endangered Species Conservation Council has a species status report that compiles the efforts of provincial, territorial and federal monitoring programs. The National Museum of Natural Sciences has an atlas of rare plants in Ontario. While distributional data exists for ferns, further research is needed to determine the impacts of water withdrawal on these organisms.

**Conifers**

Conifers are gymnosperms meaning that they have "naked seeds" that are grown in cones and not visible (Starr, 2000). They generally have scale-like or needlelike leaves and bear seeds exposed on cone scales. The Great Lakes - St. Lawrence River basin is home to a variety of conifers including pines (*Pinus* spp.), spruces (*Picea* spp.), firs (*Abies* spp.), cypress (*Taxodium* spp.) and cedars (*Thuja* spp.). Many conifers are well adapted to moderate or dry sites, and a few are able to exist on wet sites. Examples of these hydrophytic (moisture loving) plants include the bald cypress (*Taxodium distichum*) and balsam fir (*Abies balsamea*), with balsam fir being able to tolerate a wide range of sites from nearly dry to wet.

Conifers, like all plants are dependent on water. However, a reduction in water tables will likely have little affect on most of these species. Bald cypress will likely be the most affected by water withdrawals, although no data exists to back this statement. Most important to the health of all plants is soil moisture. Lack of soil moisture will cause a reduction in photosynthesis, limits the uptake of $CO_2$, and restricts the mass movement of nutrients into the roots (Kimmins, 1987).

Several agencies collect distributional and ecological data on conifers, however little is know on how water withdrawals affect these trees. The USDA Forest Service has distributional and biological information on conifers in the Great Lakes - St. Lawrence River basin. The NRCS has distributional and biological information for conifers in the Great Lakes - St. Lawrence River basin. NatureServe also has distributional information on conifers in the Great Lakes - St. Lawrence River basin. The National Biological Information Infrastructure has online information on conifers of the Great Lakes - St. Lawrence River basin. Environment Canada has biological information for the St. Lawrence River and in conjunction with the USEPA has created the SOLEC indicator database for the Great Lakes - St. Lawrence River basin. The OMNR has distributional data for conifers in Ontario. The

National Museum of Natural Sciences has an atlas of rare conifers in Ontario. Further research is needed to identify effects of cumulative water withdrawal on the sustainability of conifer stands across the basin.

**Flowering Plants**

Flowering plants, also known as angiosperms, produce reproductive structures commonly referred to as flowers. Many flowering plants evolved with pollinators (i.e., birds, insects and other animals) which contributed to their successful existence on the land for over 100 million years (Starr, 2000). These plants play a major role in everyday life and range in species from grasses to perennials, trees and shrubs. They provide the ecosystem with clean air and water, food and medicine. All plants remove $CO_2$ from the air, producing clean air to the ecosystem. They also stabilize the soil with their roots and prevent erosion. Wetland plants filter sediments and pollutants from drinking water. Nearly all fruits and vegetables come from flowing plants. Several medicines are derived from plants, including aspirin, atropine and cocaine.

Alterations of the hydrologic regime will likely affect plant species. Certain plants are adapted to various moisture and light levels. Changes in water quantities and/or light levels lead to changes in the plant species assemblage, altering the habitat, the animals that depend on that habitat and quite possibly the ecosystem (Kimmins, 1987). A single species can play a crucial role, having a kind of domino effect on the community that is disproportionate to its abundance (Mackenzie and Ball, 2001). Water shortages lead to the development of less dense vegetation which leads to low productivity (Kimmins, 1987). Alterations in groundwater flow rates are most likely to severely affect aquatic and semi-aquatic plant species and the habitats in which they live (Bay, 1967), while upland plants or those adapted to drier sites will display little if any changes.

The USDA Forest Service has distributional and biological information on plants in the Great Lakes - St. Lawrence River basin. The NRCS has distributional and biological information for plants in the Great Lakes - St. Lawrence River basin. The USGS has image, biological and distributional data for aquatic plants of the Great Lakes. The USGS also has distributional data for plants along the upper Mississippi River. The NOAA is creating distributional and biological databases on invasive species of the Great Lakes. NatureServe also has distributional information on plants in the Great Lakes - St. Lawrence River basin.

The National Biological Information Infrastructure has online information on plants and animals of the Great Lakes - St. Lawrence River basin. The Great Lakes Indian Fish and Wildlife Commission have online distributional and biological data on invasive plant species in Michigan, Wisconsin and Minnesota. Environment Canada has biological information for the St. Lawrence River, and in conjunction with the Great Lakes, have created an indicator database full of species information for the Great Lakes - St. Lawrence River basin. The OMNR has distributional data for plants in Ontario. The Canadian Endangered Species Conservation Council has an orchid status report that compiles the efforts of provincial, territorial and federal monitoring programs. The National Museum of Natural Sciences has created an atlas of rare plants in Ontario. While many agencies collect information on flowering plants, more research is needed to determine the impacts of water withdrawal on these organisms.

**Invertebrates**

Nearly 90 percent of the world's animal species are invertebrates, animals lacking backbones (Starr, 2000). Insects, the most diverse group of animals, and mollusks are common invertebrates in the Great Lakes - St. Lawrence River region. Many insects are important pollinators, ensuring seeds for next year's plants and agricultural crops. Monarch butterflies are pollinators and travel thousands of miles to their wintering grounds in Mexico. These invertebrates provide an important food source for many animals.

In the terrestrial environment, invertebrates provide food for a number of primary consumers, including moles, amphibians, snakes, turtles, birds, raccoons and opossums. Aquatic invertebrates form a large base of the aquatic food web, providing food for a number of fish, turtles, amphibians and waterfowl (EC, 2000). Aquatic invertebrates spend part or all of their life cycles in the water and include insects (such as *Diporea* spp.), crustaceans, mollusks (including native and zebra mussels) and worms.

Changes in water quantity can have great impacts on invertebrates. Low water levels can lead to higher concentrations of pollutants, creating very poor environmental conditions where few organisms survive. Insects such as black fly larva or leaches are common in these environments.

Reduction in flow can also alter the macroinvertebrate community causing some species to increase and others to decrease in abundance (Wood, 1998) Also, invasive invertebrates such as zebra mussels, can impact available water to industry and the public by clogging water intake valves due to their proliferation.

The USGS has compiled distributional and biological information for native and non-native invertebrates in the Great Lakes. The USGS also has compiled ecological data for the Lake Erie nearshore, data on the linkage between sediment contaminants and the health of fish and invertebrate communities in Lake Erie and information on burrowing mayflies in the Great Lakes - St. Lawrence River region. NOAA has information on the long-term trends of macroinvertebrate populations in southern Lake Michigan. NOAA also has compiled zebra muscle data from Saginaw Bay and is currently working on an online database of invasive species of the Great Lakes - St. Lawrence River region.

The USEPA is monitoring the bottom-dwelling invertebrates, wetland invertebrates, native freshwater mussels, mayflies (*Hexagenia* spp.) and benthic amphipods such as *Diporeia* species of all the Great Lakes and in conjunction with Environment Canada they have created a SOLEC indicator database full of species information for the Great Lakes - St. Lawrence River basin. NatureServe has distributional information on invertebrates in the Great Lakes - St. Lawrence River basin. Environment Canada has compiled biological information for the St. Lawrence River. The OMNR has distributional data for invertebrates in Ontario. The Canadian Endangered Species Conservation Council creates butterfly status reports from provincial, territorial and federal monitoring programs. While extensive data exist for invertebrates, further research is needed to determine how water withdrawals will impact these organisms.

**Fish**
Over 100 species of fish live in the Great Lakes - St. Lawrence River basin (EC, 2000). Fish inhabit a variety of aquatic ecosystems from the open waters of the Great Lakes to wetlands, streams and rivers. These fish have evolved to depend on the structural diversity and variable flow inherent to these systems. Deforestation, pollution, over fishing and invasive species have devastated native fish fauna. Several species of ciscoes, a unique deepwater fish, are now extinct. Even with the detrimental changes to the Great Lakes' environment, the variety of fish in these lakes remains among the richest in North America (EC, 2000).

Aquatic ecosystems are defined by hydrologic processes and any changes in water quantity can have a great impact on fish species (McKnight, 1998). Yellow perch, lake trout and whitefish numbers are declining in the Great Lakes (TNC, 1997). Physical alteration, habitat loss and degradation, water withdrawal, overexploitation, pollution and the introduction of invasive species all contribute to declines in native freshwater species. Building a dock, draining a swamp and clearing natural debris from the water alter aquatic habitats and often make them unsuitable for the resident species (TNC, 1997). This decreases the biodiversity of an area and alters the ecosystem (Gowing *et al.*, 1998).

Fish depend on the topography, substrate type and cover structures for feeding, hiding and reproduction. Sedimentation, channelization and dredging are all activities that change the structure and composition of the bottom and make it inhabitable for native fish species (TNC, 1997). Channelization and bank stabilization are processes for straightening a river and smoothing its sides. This results in low habitat heterogeneity, higher water velocity and the elimination of shallow-water and floodplain habitats (TNC, 1997). Channelization eliminates species that employ slow-moving waters in their life cycle. In the process of straightening a river, marshes are destroyed and once functioning floodplains are deemed useless along with fish, such as catfish and bullheads, which utilize the floodplain in their life cycle. High suspended sediment levels, low dissolved oxygen levels and high water temperatures, effect the quality of aquatic habitat, with resulting impacts on fish health and population sizes.

Fish migrate to spawn, feed, reach rearing areas and seek refuge from predators or harmful environmental conditions such as freeze-up of a lake or stream. The success of upstream migration is limited by the presence of barriers which can impede or even eliminate the passage of fish. If the migrating fish do make it upstream, they're often too exhausted to spawn. If they have to spawn in densely-populated downstream areas, their offspring are often forced to compete for any available nursery habitat. If migration is delayed or halted by barriers, the life cycle may be disrupted resulting in limited populations.

The USGS has compiled long-term biological and contaminant data, as well as distributional and biological information of native and non-native fish in the Great Lakes. The USGS also has information on the spatial movements of lake trout in Lake Huron, ecological data for the Lake Erie nearshore, data on the linkage between sediment contaminants and the health of fish and invertebrate communities in Lake Erie, predator prey data for Lake Superior and distributional data on species in the upper Mississippi River system. The National Park Service has compiled fish studies near Isle Royal. The NOAA has fishing records for the U.S. waters of the Great Lakes and is currently developing online distributional and biological information for Great Lakes aquatic invasive species. The NOAA is also developing a model to depict the influence of lake dynamics on fish populations and a report on the long-term and recent changes in Lake Michigan's food web. NatureServe has distributional data and information on fish in the Great Lakes. The National Biological

Information Infrastructure has online information on fish of the Great Lakes - St. Lawrence River basin.

The Ohio Department of Natural Resources (ODNR) has spatial data on larval walleye in western Lake Erie. The Michigan DNR has biological information about fish in Michigan. The Michigan Department of Environmental Qualilty (MDEQ) has information on the inland fish of Michigan. The USEPA and Environment Canada have created the SOLEC indicator database with species information for fish habitat, Salmon and Trout, Walleye, Lake Trout, Lake Sturgeon, Sea Lamprey, Spottail Shiners, preyfish, nearshore and wetland fish of the Great Lakes - St. Lawrence River basin.

Environment Canada has biological information for the St. Lawrence River, has spawning and migration information for the fish of the Great Lakes shorelines and GIS data on the effects of effluent on fish in the Canadian waters of the Great Lakes. The OMNR has distributional data for fish in Ontario and a report on the effects of fish habitat modification in Batchewana Bay, Lake Superior. The Canadian Endangered Species Conservation Council has a species status report that compiles the efforts of provincial, territorial and federal monitoring programs. The Great Lakes Sport Fishing Council has distributional and biological information on invasive species and their effects on the Great Lakes.

The Great Lakes Fishery Commission has compiled historic information on commercial fisheries and an online database of fish habitat for the Great Lakes. The Lake Huron Technical Committee has a GIS inventory of aquatic resources for Lake Huron and is currently integrating basin-wide data. A variety of agencies are conducting research on fish, although little is being done to determine the impacts of cumulative water withdrawal on these organisms.

**Amphibians**

Amphibians are cold-blooded vertebrates that have a dual life cycle, generally developing in the water and spending most of their adult life on land. Not only can they breath through their gills (if present) and their nose/mouth, but also they can use their skin as a respiratory surface for gas exchange (Starr, 2000). The Great Lakes - St. Lawrence River region is home to 32 species of amphibians which include tiger salamanders (*Ambystoma tigrinum*), central newts (*Notophthalmus viridescens*), leopard frogs (*Rana pipiens*), bullfrogs (*Rana catesbeiana*) and spring peepers (*Pseudacris cruicifer*) (Fuller *et al*., 1995). Amphibians are major consumers of insects, with individual frogs capable of eating hundreds of insects each day (Starr, 2000). These animals provide an abundance of food for fish, other amphibians, snakes, turtles, lizards, raccoons, opossums, and foxes.

Amphibians depend on water during early development and reproduction. They are often used as indicators of environmental health since they are exposed to elements both in the water and on land. A reduction in water would likely lead to a decrease in available forage and breeding habitats. It is likely that water withdrawals will affect the abundance of amphibians, however, research is lacking on the impacts of water withdrawal on these animals.

The USDA Forest Service has compiled distributional and biological information on amphibians in the Great Lakes - St. Lawrence River region. The USGS has distributional and biological information, as well as long-term monitoring programs, on amphibians throughout the Great Lakes - St. Lawrence River region. The USGS also has locations and information about amphibian malformations and invasive species.

The USEPA and Environment Canada have created the SOLEC indicator database with information on wetland amphibian communities for the Great Lakes - St. Lawrence River basin. NatureServe has distributional data and information on amphibians in the Great Lakes. The National Biological Information Infrastructure has online information on amphibians of the Great Lakes - St. Lawrence River basin. The National Wildlife Federation has a volunteer frog monitoring program in the Great Lakes - St. Lawrence River region.

The U.S. and Canada have teamed together to monitor birds and amphibians of marshes in the Great Lakes - St. Lawrence River region. The Michigan and Minnesota DNRs have frog population and distribution information from volunteer frog call surveys in their states. The Wisconsin DNR and the Nature Conservancy have compiled distributional, biological and historic reptile and amphibian information. Environment Canada has amphibian information for the St. Lawrence River. The OMNR has distributional data for amphibians in Ontario. The Canadian Endangered Species Conservation Council has a species status report that compiles the efforts of provincial, territorial and federal monitoring programs. Further research is needed to study how changes in water quantity and movement influences amphibians.

**Reptiles**

Reptiles are cold-blooded vertebrates with tough, dry, scaly skin that restricts water loss from their body. Fifty-one species of reptiles are found in the Great Lakes - St. Lawrence River basin, examples include the box turtle (*Terrapene carolina*), painted turtle (*Chrysemys picta*), snapping turtle (*Chelydra serpentina*), garter snake (*Thamnophis sirtalis*), massasagua rattlesnake (*Sistrurus catenatus*) and the five-lined skink (*Eumeces fasciatus*) (Fuller *et al*., 1995). The majority of these reptiles feed on insects, amphibians, fish, other reptiles and small mammals. Reptiles provide a food source for a number of large birds, mammals and other reptiles.

Many reptiles, specifically turtles and water snakes, are highly associated with the water. For that reason, turtle eggs are often used to determine contaminant levels in the aquatic system. Semi-aquatic reptiles spend much of their time foraging in or on the water. Some turtles even hibernate in the murky bottoms of the lakes and ponds. Little research exists on how water quantity and movement influences reptiles.

The USDA Forest Service has compiled distributional and biological information on reptiles in the Great Lakes - St. Lawrence River region. The USGS has distributional and biological information on reptiles throughout the Great Lakes - St. Lawrence River region and information on invasive species. The USEPA and Environment Canada have created the SOLEC indicator database including information on contaminants in snapping turtle eggs across the basin. NatureServe has distributional data and information on reptiles in the Great Lakes.

The Wisconsin DNR, Minnesota DNR, Michigan Natural Features Inventory, Michigan DNR and the combined Wisconsin DNR and the Nature Conservancy have distributional and biological reptile information. Environment Canada has biological information for the St.

Lawrence River. The OMNR has distributional data for reptiles in Ontario. The Canadian Endangered Species Conservation Council has a species status report that compiles the efforts of provincial, territorial and federal monitoring programs. Further research is needed to determine the impacts of cumulative water withdrawal on reptiles within the Great Lakes – St. Lawrence River system.

**Birds**
Over 130 species of birds inhabit the Great Lakes - St. Lawrence River basin (Fuller *et al.*, 1995). More than 30 species of waterfowl use the Great Lakes and their coastal wetlands, with the greatest species diversity occurring during the spring and fall migrations (EC, 2000). The Great Lakes - St. Lawrence River basin is situated along the Mississippi and Atlantic flyways which bring hundreds of millions of birds through the area twice each year. These birds play important roles seeds dispersers, insect eaters and rodent controllers. They also support tourism with large numbers of bird-watching enthusiasts coming into the region during migration.

Water is a very important habitat component of many birds' life cycles. Water is both consumed for rehydration and bathed in for cleanliness. Several species of birds are also highly associated with the water, spending the majority of the day in the water foraging, these animals include the bald eagle (*Haliaeetus leucocephalus*), ducks (*Anas* spp.), shorebirds, and loons. Many shorebirds and waterfowl often migrate north and south hopping from one waterbody to the next. Because these animals are highly dependent on the water, it is likely that lower water supplies, and hence water levels, will negatively impact these species.

Several agencies collect data on birds. The USDA Forest Service has distributional and biological information on birds in the Great Lakes - St. Lawrence River region. The USGS has several projects with distributional and biological information on birds throughout the Great Lakes - St. Lawrence River region and information on invasive species. The U.S. Fish and Wildlife Service (USFWS) has distributional and biological information on nesting birds in Pennsylvania.

The USEPA and Environment Canada have created the SOLEC indicator database with information on breeding bird diversity and abundance, coastal wetland bird community health and contaminants in colonial nesting waterbirds for the Great Lakes - St. Lawrence River basin. NatureServe has distributional data and information on birds in the Great Lakes.

The Michigan DNR has compiled information of birds in Michigan and provides access to this information on-line. Michigan State University has a report on the limiting factors of waterfowl in Great Lakes wetlands and deep water habitats. The Wisconsin Society for Ornithology has abundance, distribution and biological information for breeding birds in Wisconsin. New York Department of Environmental Conservation (NYDEC), Ohio DNR, Illinois DNR and Ontario also have breeding bird studies for their state or province. Environment Canada has biological information for the St. Lawrence River and distributional and biological information for birds in Ontario. The OMNR has distributional data for birds in Ontario.

The Canadian Endangered Species Conservation Council has a species status report that compiles the efforts of provincial, territorial and federal monitoring programs in Canada. The Canadian Wildlife Service conducts waterfowl surveys at Hamilton Harbor on Lake

Ontario. The U.S. and Canada have teamed up to monitor marsh birds of the Great Lakes - St. Lawrence River region. The National Audubon Society has online information on the biology and distribution of winter birds in the U.S. and Canada. Aves.net is a good source for online information on the biology and distribution of winter birds in Ohio. Although much data is currently being collected on birds, further research is needed to determine the impacts of cumulative water withdrawal on birds in the Great Lakes – St. Lawrence River system.

**Mammals**

Mammals are warm-blooded vertebrates with hair and mammary glands. Most mammals of the Great Lakes - St. Lawrence River region are terrestrial, however a few are highly aquatic including the muskrat (*Ondatra zibethicus*), water shrew (*Neomys fodiens*), beaver (*Castor canadensis*), moose (*Alces alces*) and river otter (*Lutra canadensis*). The mammals of the Great Lakes - St. Lawrence River region assume their positions at the top of the food web from primary producers to top consumer. Many of the top predators such as the gray wolf (*Canis lupis*), the bobcat (*Lynx rufus*) and the mountain lion (*Felis concolor*) have disappeared from their traditional territory leading to large populations of deer and heavily browsed forests.

Mammals are mostly composed of water and highly depend on it for their survival. Lakes, ponds, wetlands and streams are utilized by mammals daily for drinking water. Some mammals, such as muskrats, beavers and humans alter the flow of streams and rivers by building dams. Unlike human dams, the dams built by beavers and muskrats are highly susceptible to damage by floods and other natural events. Beaver dams, while considered annoying to some, create habitat for many other species including trout, frogs, salamanders and moose. These dams also provide diversity in the form of plant species assemblage and varying habitat types.

Water withdrawals will greatly impact mammals by decreasing the amount of available plant for food (Muzik, 1998). Muzik (1989) found that muskrat populations decreased six fold with a 38% loss of surface water and a 36% loss of shoreline. This loss of shoreline and surface water also affected fish and waterfowl habitats.

The USDA Forest Service has distributional and biological information on species in the Great Lakes - St. Lawrence River region. The USGS has information on invasive species throughout the Great Lakes - St. Lawrence River region. The USEPA and Environment Canada have created an indicator database full of species information for the Great Lakes - St. Lawrence River basin. NatureServe has distributional data and information on animals in the Great Lakes. The Michigan DNR has biological information online for Michigan mammals. Environment Canada has biological information for the St. Lawrence River. The OMNR has distributional data for animals in Ontario. The Canadian Endangered Species Conservation Council has a species status report that compiles the efforts of provincial, territorial and federal monitoring programs.

Further studies should be conducted to determine likely effects of cumulative water withdrawal on mammals within the Great Lakes – St. Lawrence River system.

## Organisms Data and Information Inventory

Presented hereafter is an inventory of data and information holdings related to organisms within the Great Lakes - St. Lawrence River basin. The inventory does not contain all available information on organisms in the Great Lakes - St. Lawrence River basin, especially information generated from private industries and small academic projects. Rather, it is an inventory of information and data holdings from federal agencies and regional conservation initiatives.

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